Automated Fourth-Harmonic Analyzer

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This article describes the final design of a field portable microprocessor-based, microwave measuring and analysis instrument to be used for S-band transmitter fourth-harmonic power analysis and its impact on X-band reception in a dual S-X-band system.

I. Introduction

The requirement for a fourth-harmonic power analyzer has been previously discussed in *The Deep Space Network Progress Report 42-34*, pp. 39-42. The primary reason for the design of an instrument to automate the measurement is the speed gained by substituting a computer for the human operator. Through automation, the final results can be automatically calculated from raw measurement data in real time. Calibration data are measured and stored, and then used during the actual test to reduce systematic errors. Because all calculations are performed instantly, a hard copy of the corrected data is available immediately upon completion of the measurement.

This application also provides a test bed for generalized applications of microprocessors to the DSN to increase the capabilities of test equipment.

II. Hardware

A simplified system block diagram (Fig. 1) and the photographs (Figs. 2, 3) detail the major hardware elements of the instrument. The instrument was designed around the Intel 8080 central processor unit (CPU). All components of the design are modular to the extent that they can be used as stand-alone building blocks in systems with similar design requirements. The control interface between the microprocessor and the measurement instruments is via the bus standard adopted by IEE (No. 488) and ANSI (MC 1.1). This is a standard which defines the electrical, mechanical, and functional aspects of an instrument interface. The hardware is designed so that on turn-on the program immediately controls the CPU.

The instrument includes an internal switch that allows the operator to select a diagnostic program which will provide help in case of hardware failure. The present program with diagnostic is contained in 7K of programmable read-only memory (PROM). The hardware allows for 3K expansion simply by plugging in the additional PROM as well as space for up to 8K additional PROM provided in the layout. There is also 9K of random access memory built in, and because of the modular design, any combination of random access memory (RAM)/PROM up to 27K can be utilized. A serial input/output port with a 20-mA current loop has also been provided so that the collected data can be output for further analysis by a larger system and/or the instrument can be controlled remotely.

III. Software

The software was developed using a combination of PL/M (a high-level language) linked to assembly language to implement a program that was transportable, maintainable, and fast enough to meet the functional requirements. The program is stored in electrically erasable and programmable read-only memory.

IV. Operations

The operator is prompted how to operate the analyzer (how to start a measurement sequence, when the analyzer is ready for a new sample measurement, what port the measurement probe is in, etc.) by a built-in alphanumeric display. The program operates on each measurement [by converting the measured power to actual power using the known voltage standing wave ratio (VSWR) for the particular port] and then stores all 240 measurements. The operator can then request either the total fourth-harmonic power, or a listing (provided by a built-in printer for a hard-copy record) of each of the 240 ports and the total power.

The following is a typical operation sequence. The power meter is switched to the remote operation mode, and the power meter is internally zeroed under computer control. After the zeroing process, the operator is prompted to select starting port number and probe gain. The operator then sees the prompt photo (Fig. 4) "ready for port 'N'," at which time the probe is inserted into the appropriate port and the operator commands the instrument to make another measurement by pressing the ready switch. The instrument makes the measurement and stores the data in memory, and then prompts the operator to proceed to the next port. This operation is repeated until interrupted by the operator, or all 240 ports have been measured. The operator is then prompted to select either the full report (consisting of a listing of corrected power at every port, plus a total corrected power) or a printout of total collector power only (Fig. 5).

V. Conclusion

The microprocessor-controlled portable instrument has been evaluated in the lab (Fig. 4) with the result that, after the harmonic probe has been installed, a complete measurement can be made every 30 min by one unskilled operator when previously it took two skilled operators 1 day. The instrument's operation can be taught in less than 10 min. The dynamic measurement range is 105 dB (−70 dBm to +35 dBm) and will be extended to 185 dB (down to −150 dBm) with the completion of an RF probe design. The instrument is presently being used in the lab to evaluate the design of high-power harmonic filters, and will soon be shipped to Goldstone for measurements on the high-power transmitter.

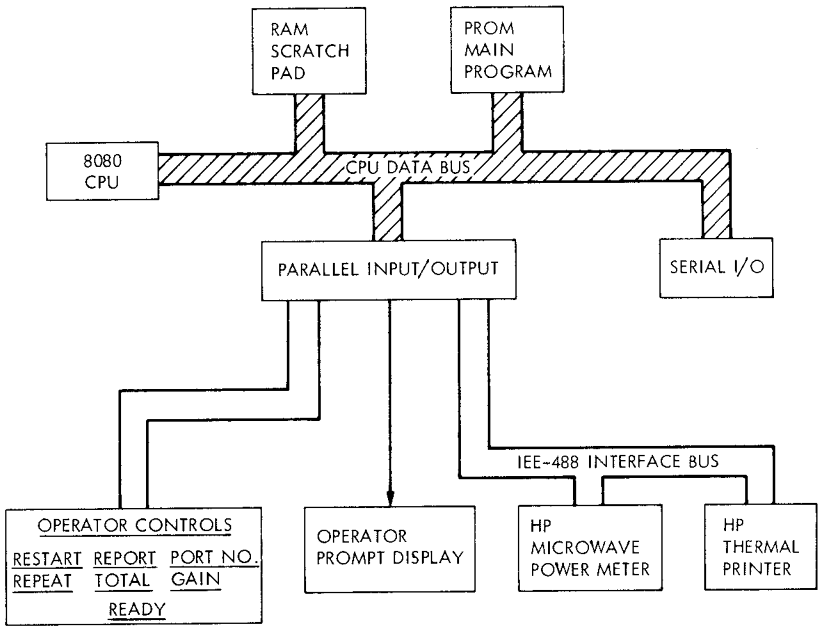

Fig. 1. Simplified block diagram (HPAS) harmonic power analyzer

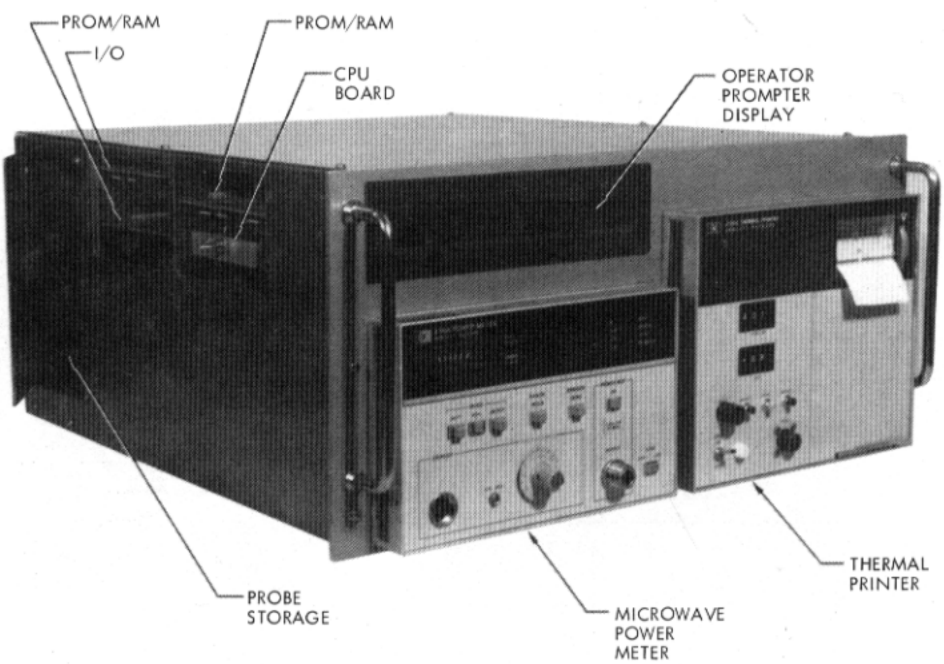

Fig. 2. Fourth-harmonic analyzer

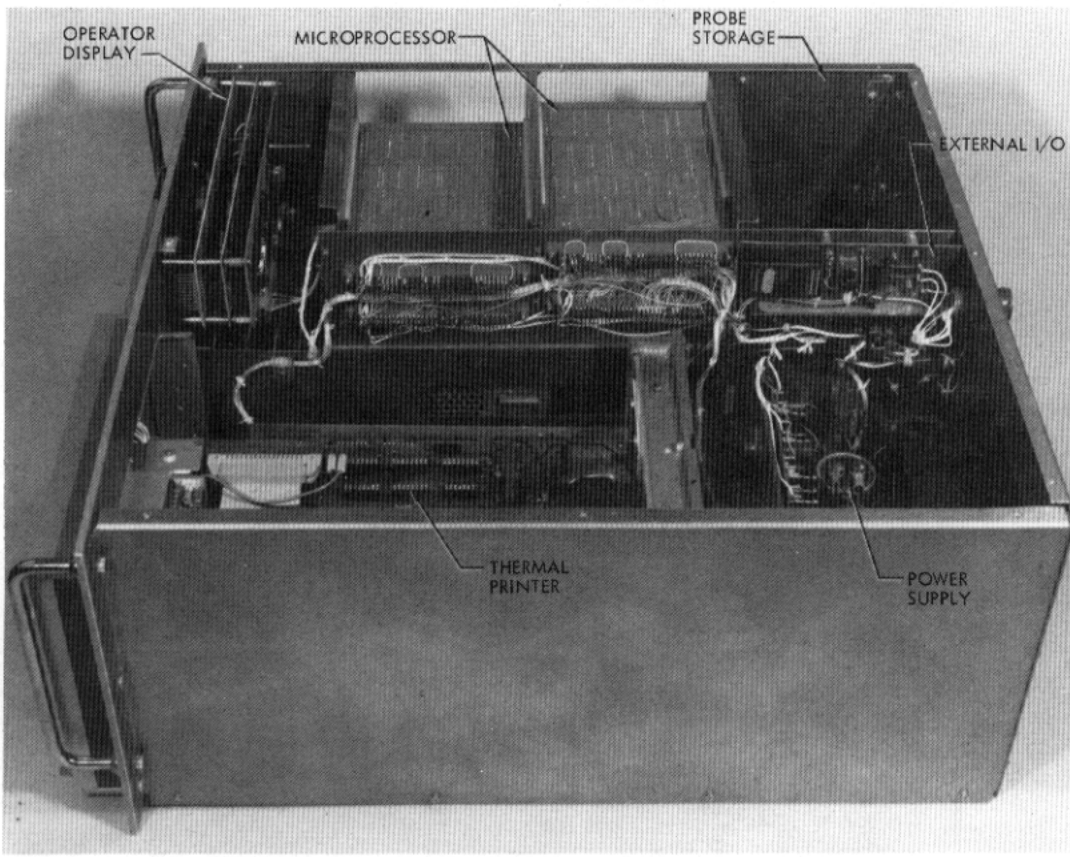

Fig. 3. Fourth-harmonic analyzer, internal view

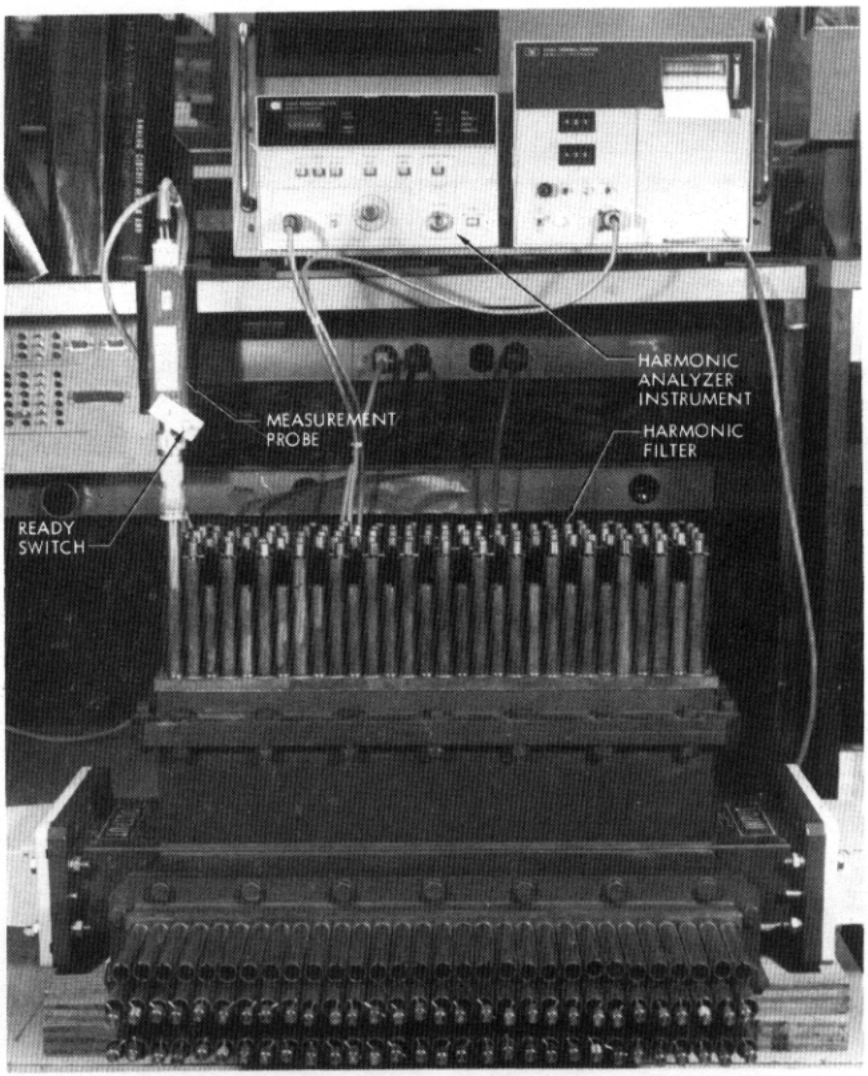

Fig. 4. Measurement setup, fourth-harmonic analyzer

TOTAL CORRECTED POWER
.25750 MILLIWATT

I30	1.0583	MICROWATT
I29	1.0471	MICROWATT
I28	1.0666	MICROWATT
I27	1.0529	MICROWATT
I26	1.0789	MICROWATT
I25	1.0718	MICROWATT
A11	1.0641	MICROWATT
A10	1.0736	MICROWATT
A09	1.0637	MICROWATT
A08	1.0524	MICROWATT
A07	1.0853	MICROWATT
A06	1.0838	MICROWATT
A05	1.0949	MICROWATT
A04	1.1403	MICROWATT
A03	1.1444	MICROWATT
A02	1.1551	MICROWATT
A01	1.1558	MICROWATT

Fig. 5. Typical data printout